CHAPTER 5

THE STRUCTURES OF THE CHROMOSPHERE AROUND AN ISOLATED SPOT

SUMMARY

Dark features on H-alpha filtergrams around an isolated spot on 16 August, 1967 are studied. Most of them show horizontal motions of material toward the spot while some of them show loop structures. The long threads which are the darkest features in the filtergrams show downward motion to the solar surface. They are interpreted as prominences. A model of magnetic field configuration around the spot in the chromosphere is presented.

5.1 INTRODUCTION

H-alpha filtergrams of the solar disk show complicated patterns. The character of the structures depends strongly on the position within the line profile where the observation is made and on the region being observed. Thread shaped features dominate in and near the line centre in active regions. There are more inclined, elongated dark mottles than those in undisturbed regions. The pattern close to spots seem to be a kind of vortex. There is a clear difference between the chromospheric structures around the spot in the red and violet wings. BECKERS (1962) have studied the Evershed velecities in the chromosphere. He found that there are inflow motions of velocity 45 km./sec and of lifetime about 9 hours from the outer boundary of the penumbra out to two sunspot radii. The moving matter flows in along channels and the velocity vector makes an angle of about 13° with the solar surface, which suggests that the matter is constrained to flow along lines of magnetic force.

KIEPENHEUER (1967) assumed that the thread and loop features found in the active chromosphere represent a kind of magnetic flux tubes, originating along the border of the penumbrae and supergranules and preceeding into the chromosphere and corona.

The present paper describes a high resolution study of the active chromosphere at different heights which leads to a three dimensional model of chromospheric structures around an active region.

5.2 DATA

Filtergrams of an active region near the centre of the solar disk were taken by Dr. Rawi Bhavilai on his visit to the Capri Observatory in Italy in August, 1967 with a 0.5 A^{o} bandwidth Halle filter attached to the domeless Coudé refractor. The diameter of the solar image is 150 mm. Observations were made on an old spot on 16 August located at latitude 30^{o} and longitude 256^{o}. The sequence of images were obtained while the filter was -1.0, -0.75, -0.5, -0.25, 0.0, +0.25, +0.50, +0.75 to +1.0 A^{o} from the H-alpha line centre. The first frame is at H_{α} +0.25 A^{o} at the universal time 08^{h} 19^{m}. Time lapse between exposures is 3 seconds. Nine consecutive frames of good quality were selected between 08^{h} 20^{m} to 08^{h} 21^{m} and printed on high contrast Agfa BS1 paper with an enlargement of 8 times original size. The print scale is 10 mm to 18 sec of arc.

5.3 REDUCTION

The features appearing in H-alpha filtergrams at different positions within the line profile are studied by the method of superimposing. Maps of these filtergrams are made by

1) tracing of the features on the prints using transparent papers, and

2) printing with enlargement on high contrast films.

About 50 dark fibrils around a spot are studied by superimposing these maps. Eye estimate of the intensities of the fibrils in comparison with the background is made. Then the profile of each feature is plotted in comparison with the average H-alpha line profile near sunspot prepared by WHITE and WILSON (1966). Though this profile refers to an area near the solar limb (about 50000 km from the photospheric "inner" limb) while the fibrils being studied in this report are about 100000 km from the limb, the error is not significant.

Plate 5.1 shows a filtergram of an area around a spot centred on H-alpha. The most obvious features are fibrils which are dark filamentary structures with a thickness of 1 - 5 sec of arc and a length of 10 - 30 sec of arc imbedded with bright filamentary fine structures called "faculae", and large bright regions around the spot called the "chromospheric plages". The fibrils often cluster together and are elongated and bend almost in the same direction around the spot, with a bright region at the centre of the cluster.

Plate 5.1. - Hα filtergram of an isolated sunspot near the limb, taken 16 August, 1967 at 0.0 Å, obtained with a 0.5 Å bandwidth Halle filter. (Photo by R. Bhavilai, with the domeless Coudé refractor, Capri Observatory.)

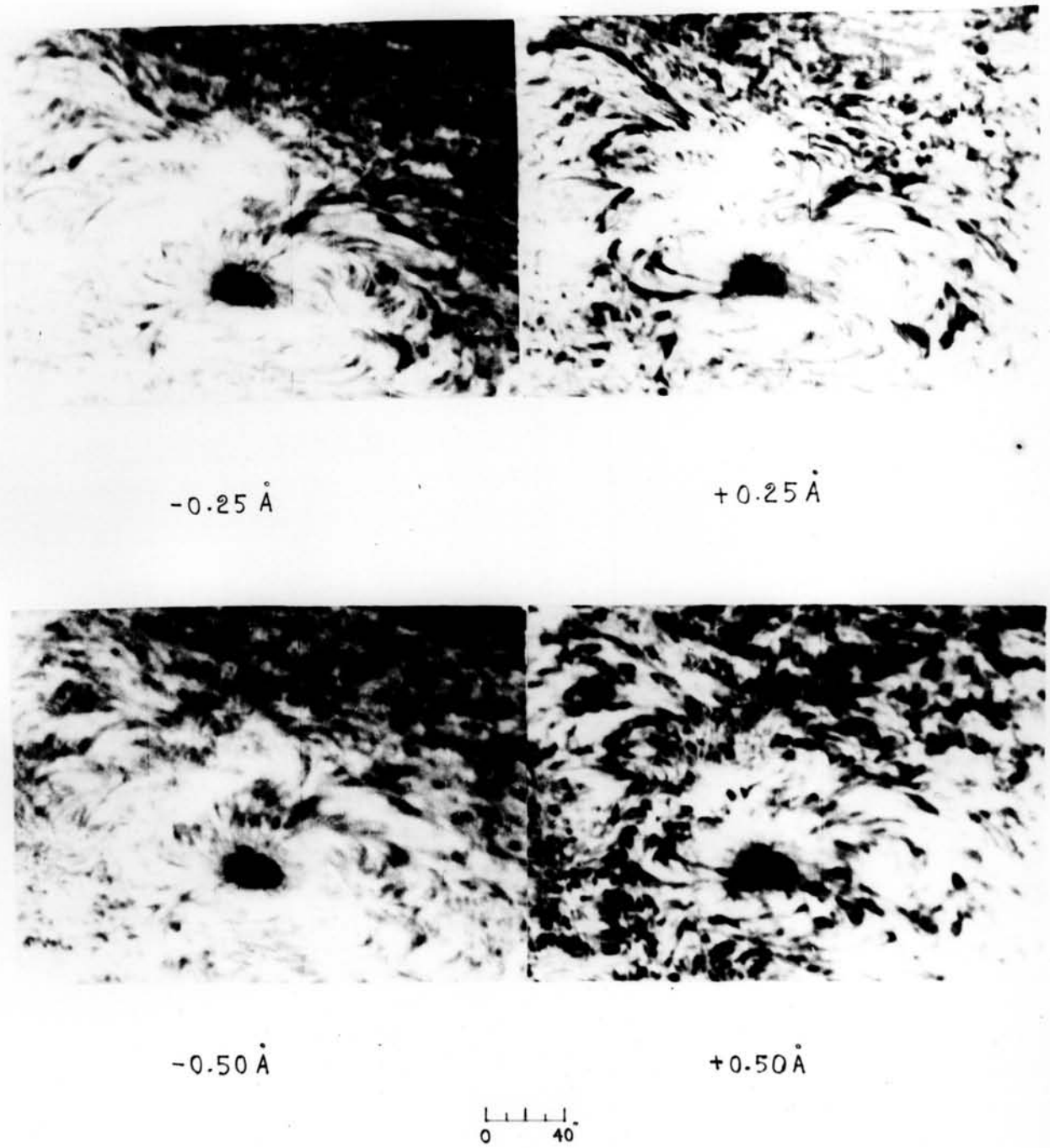


Plate 5.2.— H_α filtergrams taken on 16 August 1967, with a 0.50 bandwidth Halle filter showing the differences between the Chromospheric structures around the spot in the red and the violet wings.

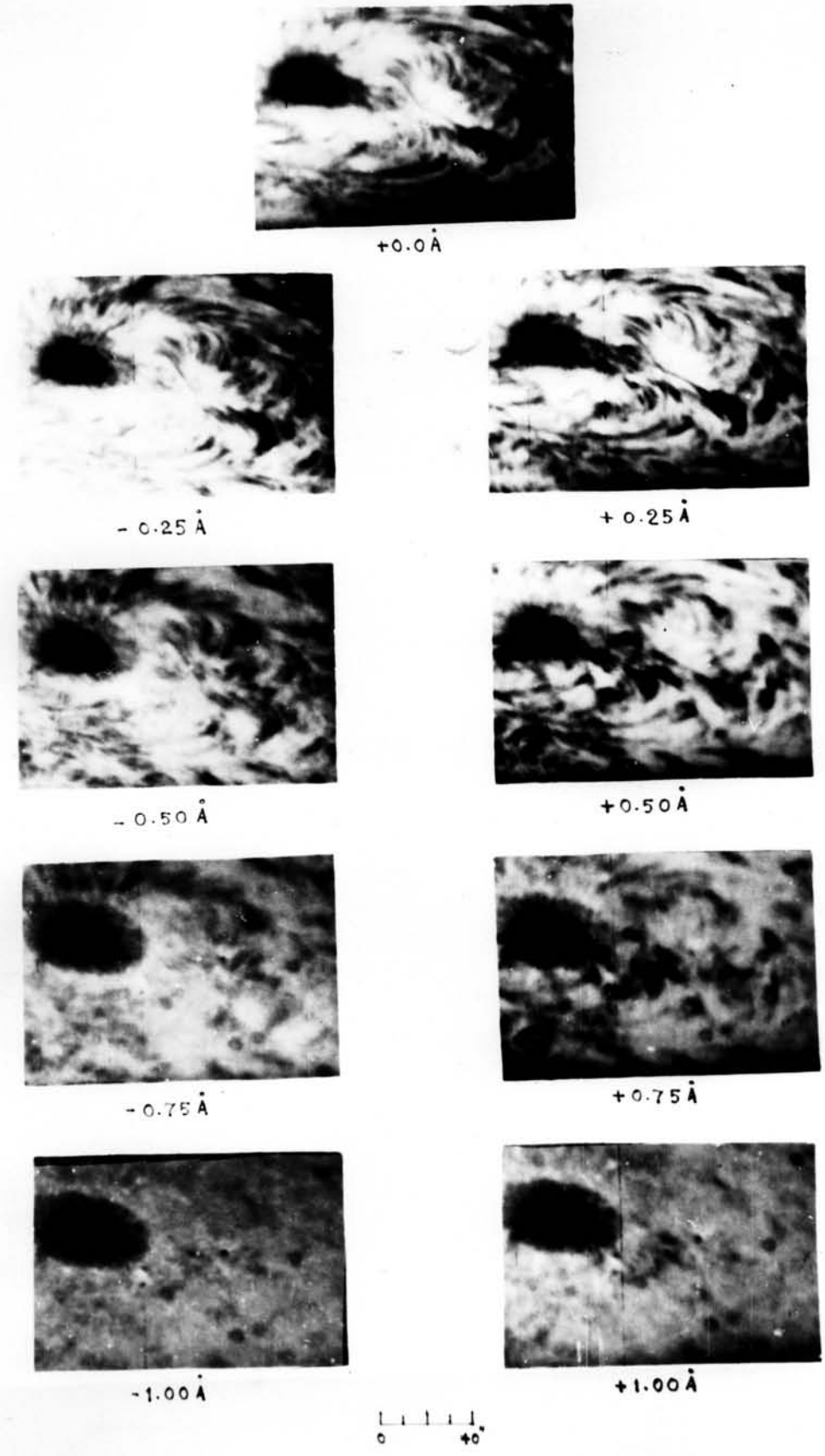


Plate 5.3.– Vortex structures in the chromosphere near a sunspot of 16 August 1967, at different positions of the H_α line profile.

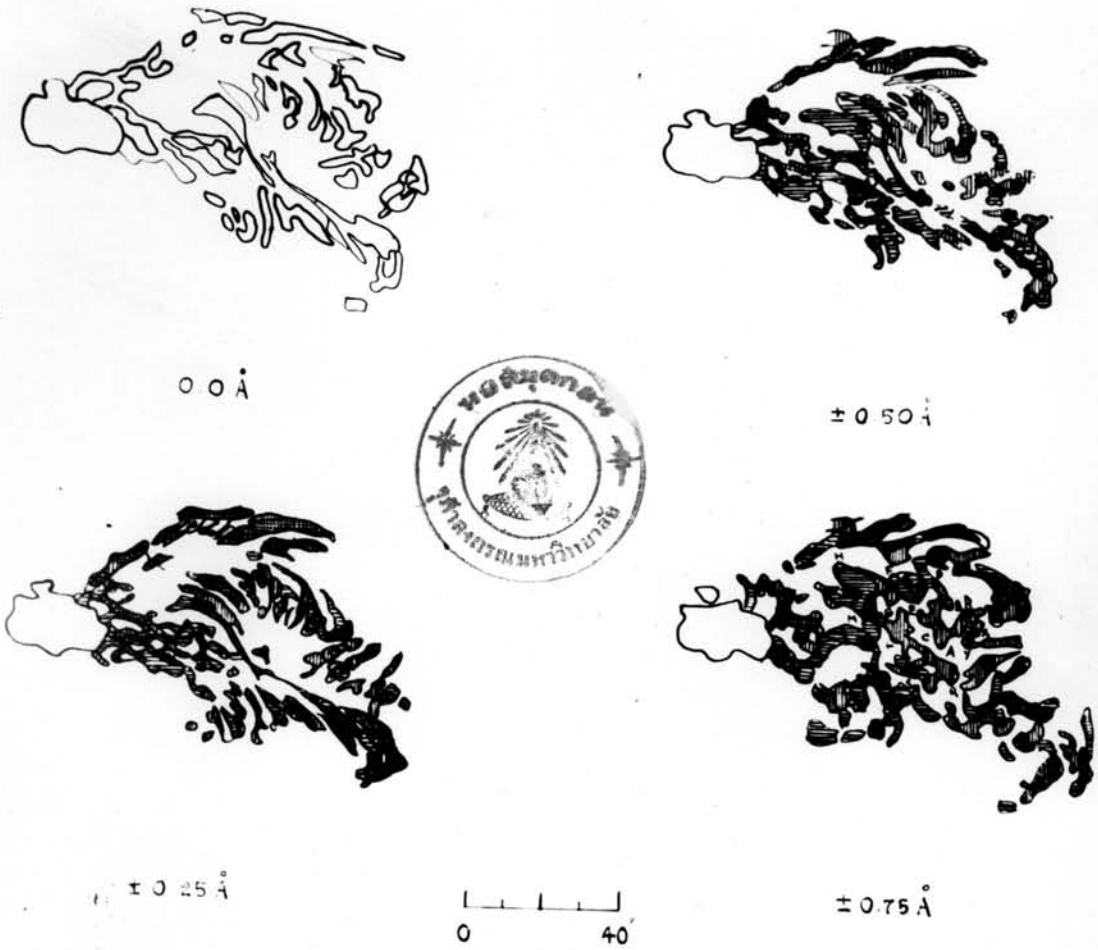


Plate 5.4 – Superimposing maps of selected pairs of wavelengths of the vortex structure in Plate 5.3

An underexposed of the umbra of the spot, showing the core of the umbra near the left end.

Plate 5.5

Plate 5.2 shows the difference between the chromospheric structures around the spot in the red and in the violet wings. In the violet wing the limb side of the spot shows a dark diffuse area while the rest of the area around the spot is bright. In the red wing the dark material on the side of the spot towards the centre of the disk shows resolved structures and is darker than the diffuse dark features at limb side in the violet wing. BECKERS(1962) interpreted these features as due to the large velocities in the dark structures directed towards the spot. From the diagram in Figure 5.1 showing the prominence of recessive velocities, it can be seen that the motion is horizontal to the solar surface.

Most of the dark, long thread-shapedfeatures seen in and near the line centre show red shifts which indicate downward motion of matter on the solar surface. They are interpreted as quiet filaments or prominences with downward motion as shown. in figure 5.2 (a) and (b)

In the area outside the region where the flow of material is generally towards the spot, ten fibrils which are studied show loop structures. This is inferred from the existence of upward motion and downward motion in pairs of adjacent fibrils. Two isolated loop structures are shown in Figure 5.3. Loop structures found in the vortex on the right of the spot show material flow towards the boundary of the spot. Three loop structures outside the vortex have a reverse direction of material motion, i.e. outward from the boundary of the spot. Plate 5.3 shows filtergrams of the vortex structure at different positions on the line profile while Plate 5.4 shows the superimposed maps of selected pairs of wavelengths. The three dimensional model can be constructed as in Figure 5.4.

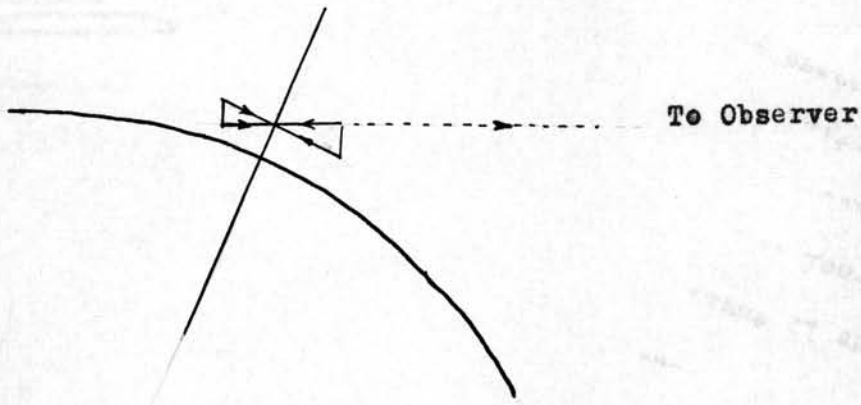
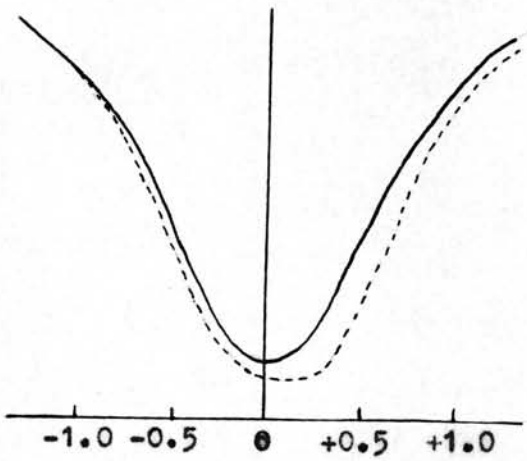
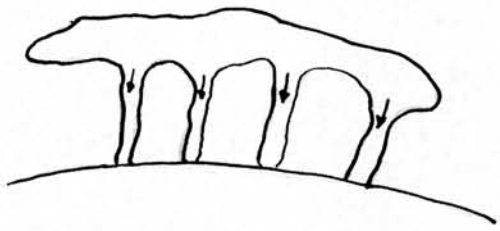


Figure 5.1 Diagram showing the prominence of recessive velocities, the motion is horizontal toward the spot.



(a)



(b)

Figure 5.2 (a) Profile of H-alpha showing red shift of fibrils, and (b) downward motion of prominence.

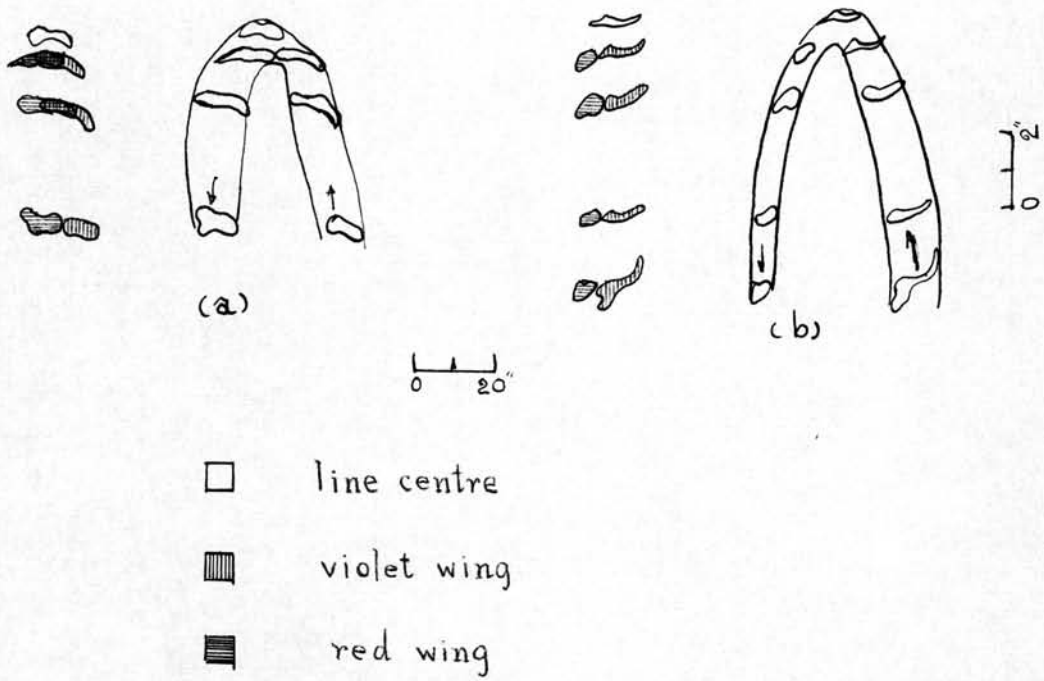


Figure 5.3.- Loop structures found in the chromosphere around the spot. Both (a) and (b) are located in Plate 5.1.

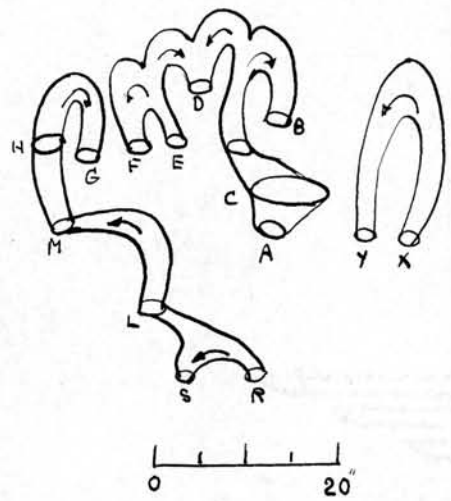


Figure 5.4 - Three dimensional model of loop features in the vortex structure shown on Plates 5.3 and 5.4.

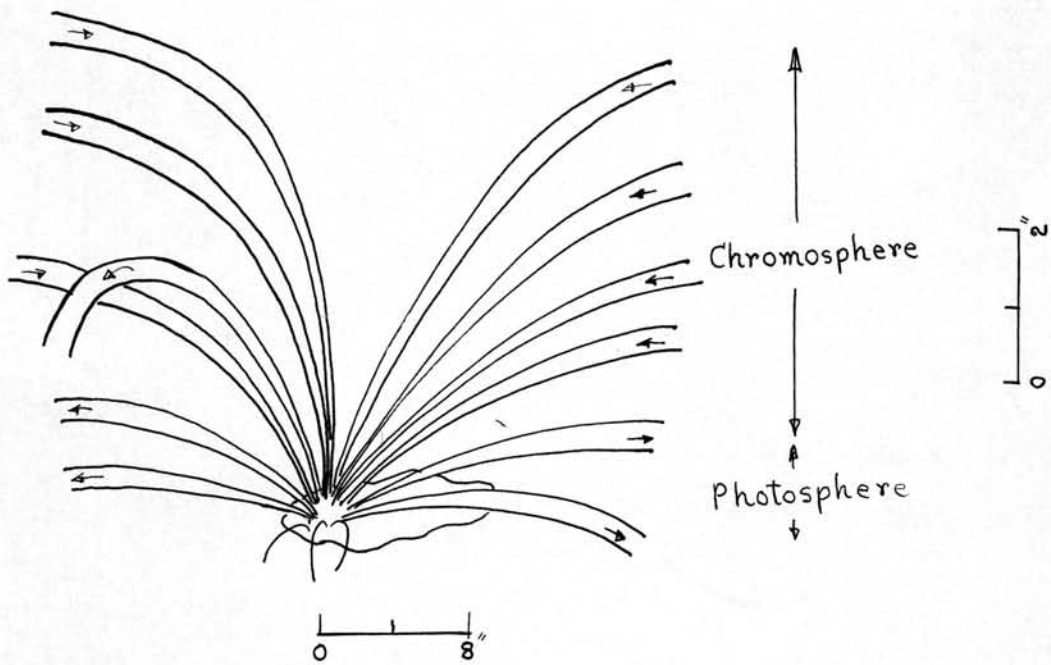


Figure 5.5.– A model of magnetic lines of force around a sunspot.

5.4 RESULTS

The dark elongated structures around a sunspot can be classified into the following catagories :

1. Features in the immediate surrounding of the spot which have motions towards the centre of the spot.

2. Loop structures, most of them being outside the region of inward motion.

3. Prominences with downward motion to the solar surface.

5.5 DISCUSSION

From an underexposed print of the umbra of this spot (plate 5.5), it is seen that the core, which is the darkest area where the magnetic field is strongest in the umbra, is near the left end. Following BRAY and LOUGHHEAD (1964), the material flow in the surroundings of this spot can be explained thus. Lines of force emanate from the core of the umbra and then diverge into the photosphere and the chromosphere. Material flows along the lines of force. The motion towards the spot in the chromosphere shows that magnetic lines of force in the chromosphere around the spot lie horizontally with material flowing inward along the lines of force. However in the lower photosphere, Evershed found that material flows outward from a spot. Also in the lower photosphere the direction of motion is somewhat inclined downward. The model of magnetic lines of force around a sunspot can be constructed as in Figure 5.5.

Magnetic lines of force which emanate from the core to the immediate surroundings on the side near the edge of the umbra are almost vertical.

Therefore some lines of force may form arches into the chromosphere such as the three loop structures near the core where material flow upward at inner and inward at outer regions. The loop structures which were found in the vortex structure, however, have a horizontal flow toward the spot, which is the same as in the other regions of the chromosphere around the spot. The nearly vertical motion found in loop structures may be due to other effects, not the motion along the lines of force.

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